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Feasibility of Small Woody Biomass Combined Heating and Power Systems

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Woody biomass from forests is a viable source of energy for domestic as well as industrial use. Trees absorb carbon dioxide from the atmosphere during photosynthesis. Tree limbs, tops, and leaves store energy (about 8,000 British thermal units for every pound) that can be used to create renewable fuels.

This carbon–neutral cycle demonstrates that woody biomass is a source of green energy because the net amount of carbon dioxide emitted to the atmosphere is limited.

Thermochemical methods induce controlled heating of woody biomass by gasification or pyrolysis to produce a variety of liquid and gas biofuels. Energy from woody biomass can provide buildings with heat or electricity (or potentially both)—better known as combined heating and power (CHP)

Highlights...

- Woody biomass (forest debris) is an economical, viable source of green energy.
- Controlled heating of woody biomass can reduce fossil fuel consumption, lower the production of greenhouse gases, and provide a market for excess biomass.
- The use of woody biomass combined heating and power (CHP) systems for smaller facilities (5,000 to 20,000 square feet) is not economical. Biomass furnaces are economical for this size range.

Combined Heating and Power Systems—State of the Technology

Numerous conventional heating systems use woody biomass as the primary source of energy. Systems are available for small and large facilities; external boilers for providing heat to homes, wood furnaces, and entire school campuses. The "Fuels for Schools" program provides funding for these systems. Some of these large systems produce combined heat and power. The White Mountain Forest Service Headquarters (Forest Supervisor's office, ranger district office, visitor center) has a seasonal woody biomass CHP system that uses wood gas to fuel a generator. Many types of CHP systems exist. These systems include, but are not limited to, updraft, downdraft, fluidized-bed-reactor, and entrained-flow gasifiers. Updraft and downdraft gasifiers (figure 1) are more common for woody biomass materials because the fuel bed is fixed in the gasifier.

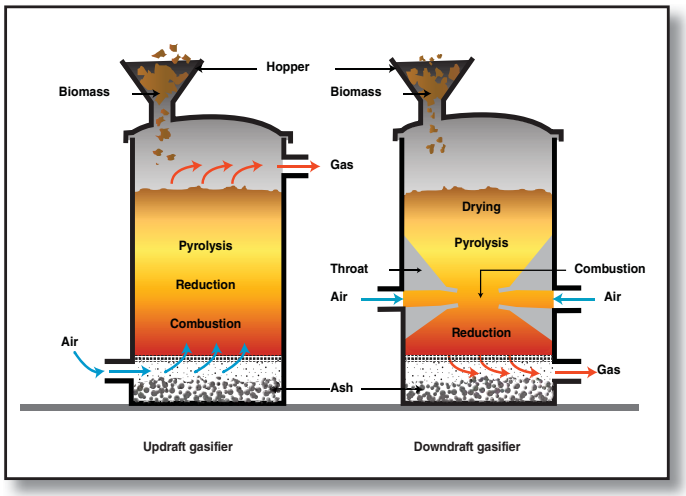

Figure 1—Updraft and downdraft gasifiers.—*Adapted with permission from Ashden*

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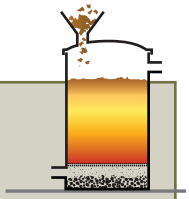

Gasification and Pyrolysis

Gasification burns solid carbonaceous material, such as woody biomass, without enough air to complete combustion. The unburned gas is known by various names: producer gas, wood gas, town gas, and others.

Pyrolysis is the decomposition of organic material through a thermochemical reaction in a reduced oxygen environment, such as a gasifier. This staged-air combustion equipment is designed to obtain both combustible gas and heat as separate products. Two types of fuel that result from pyrolysis are pyrolysis oil and syngas.

Producer Gas

Producer gas is the result of incomplete combustion. This least expensive thermochemical method requires no special additives. However, producer gas is not as energy rich as other types of fuel.

Pyrolysis Oil

For the thermochemical method called fast pyrolysis, the temperature of the gasifier is set to about 600 °C and the biomass exposure to heat is limited. This method produces a fuel known as pyrolysis oil, which can be used like crude oil.

Syngas

The high-temperature pyrolysis thermochemical method uses steam instead of air to convert the majority of the biomass to syngas, a carbon- and hydrogen-rich fuel. Syngas can be used to produce other fuels, such as ethanol, gasoline, and diesel.

Producer gas, pyrolysis oil, and syngas can be used to power or heat a building. Alternatively, a process known as the Fischer-Tropsch synthesis converts syngas into synthetic fuels, such as synthetic diesel. Although synthetic fuels can be more versatile, the extra steps required to produce them make them less advantageous when compared to producer gas or syngas.

The difference between updraft and downdraft gasifiers is the direction of gas flow. The oxidating agent (air or pure oxygen with or without steam) enters at the top and gas is drawn off at the bottom of a downdraft gasifer. Gas flow is the reverse in an updraft gasifier: air is introduced at the bottom and gas is drawn off at the top.

Two options are available for creating a CHP system. One option is to use a boiler heated by biomass, producer gas, or syngas to power a steam turbine for electricity and provide heat through the hot water. The second option is to split producer gas or syngas into two different lines; one line powers generators while the other provides heat for various applications.

This tech tip provides a status update on the availability of CHP for smaller facilities—5,000 to 25,000 square foot buildings—the typical size of a ranger district or supervisor office. Small CHP systems would provide a greener approach to power generation by allowing buildings to reduce need for conventional power, meeting some of the needs of remote Forest Service offices. Also, the cost of woody biomass is significantly cheaper than the cost of electricity in most cases.

Factors to consider for installing a CHP system include:

- Expensive electrical costs
- Local available sources of biomass
- Labor costs to clean and operate the system

A CHP system is only viable when kilowatts per hour (kW/h) electrical costs are higher than the cost of biomass per kW/h of energy produced. A CHP system should be within 30 to 50 miles of a woody biomass source; any farther and the cost of transportation and processing is too expensive. Both large and small CHP systems require employees to clean and inspect the systems to ensure healthy and efficient operation.

Unfortunately, most companies only offer large CHP systems. Community Power Corporation, for example, used to manufacture CHP systems (known as Biomax) with capacities as small as 5 kilowatt-electric (kWe) peak power. These systems would have been ideal for smaller building applications. New CHP systems are too large and too expensive to be practical for smaller buildings.

The University of Montana Biomass project (headed by Brian Kerns) has a demonstration unit of the Biomax 25 system (figure 2). The Biomax 25 system produces a peak power of 25 kWe, generates 200,000 British thermal units per hour (Btu/h) of heat, and uses 50 pounds of wood chips per hour with a maximum combined efficiency of about 70 percent.

Figure 2—Demonstration unit of the mobile Biomax combined heating and power system.

Community Power Corporation has discontinued this system and now only manufactures large systems. The smallest system has a capacity of 100 kWe peak power.

GASEK Ltd. currently manufactures a small CHP system that produces 20 kWe of power and generates 200,000 Btu/h of heat. All Power Labs offers two CHP systems: the 10 kW Power Pallet (3 to 10 kW power output) and the 20 kW Power Pallet (6 to 20 kW power output).

The Future of Combined Heating and Power Systems

The U.S. Department of Agriculture, Forest Service Missoula Technology and Development Center (MTDC) looked at the reasons Community Power Corporation and some other companies don't manufacture small-scale CHP systems. Many customers might balk at the purchase cost and maintenance of the systems. The systems must be fed, cleaned, and monitored frequently to ensure optimal efficiency.

The installation cost per kWe of energy produced generally is much higher for CHP systems than for competing technologies. For example, the discontinued Biomax 25 CHP system had an installation price of about $11,320 per kW of peak electrical power. With such high installation costs, the time it takes for these CHP systems to pay for themselves is too long to be considered a cost-efficient energy solution. In some instances, the payback time exceeds the expected life of the system itself. Brian Kerns at the University of Montana estimates that his Biomax 25 system will be a viable energy source when the local grid energy costs exceed $0.60 per kW/h. Because the average price for electricity in the United States is $0.10 to $0.25 per kW/h, these CHP systems do not seem practical for small-scale use in the near future.

In what situations could CHP systems be useful? Larger facilities that consume more than 75 kWe of peak power usually can benefit from a CHP system. With a larger facility, a larger CHP system is needed. These larger systems typically are self-sustaining. Large hoppers store enough biomass to feed a system for weeks, automated systems control the amount of biomass used, and a computer regulates the heat and energy output accordingly. Employees still must maintain and clean the system, but the required work for a larger facility hardly affects productivity or costs.

Facilities that produce a large excess of biomass, such as sawmills, farms, or logging companies, also may benefit from a CHP system. Rather than selling their biomass or paying to ship it away, these companies could produce power from the excess material.

Dixon Ridge Farms in Winters, CA, is an excellent example of a company that produces power from biomass waste (figure 3). Their Biomax CHP system produces 50 kWe of power and 650,000 Btu/h of heat using the shells from the farm's walnut crop to offset the heat and electrical costs of their facility.

Remote areas tend to have high electrical or fuel costs. If a source of biomass is readily available in these locations, a CHP system may generate cost savings.

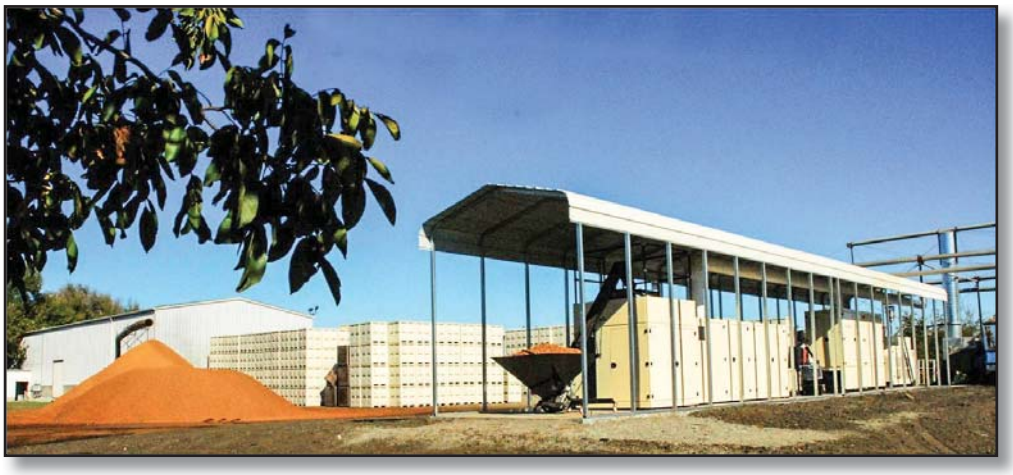

Figure 3—Dixon Ridge Farm's combined heating and power system.—*Courtesy of Community Power Corporation*

Conclusions

The Forest Service continues to look for ways that use woody-biomass energy systems to reduce its carbon footprint while meeting the policy requirements of Forest Service Handbook (FSH) 7309.11 and the Office of Management and Budget (OMB) Circular No. A-94. These requirements direct the Forest Service to invest funds appropriately, ordinarily using total life-cycle costing (present worth) analysis techniques.

Some things to remember:

- Consider all costs in terms of constant dollars, that is, exclude the effects of inflation.
- The study period for all projects should be limited to 25 years.

At this time, small CHP systems are too expensive to install and maintain for most facilities. In addition, areas and companies that can actually benefit from a system are scarce. Until electrical costs exceed the $0.60 per kW/h range or CHP system installation costs drop, these systems will not be as cost effective as many other competing technologies.

Biomass furnace heating systems can be economical for facilities in the 5,000 to 20,000 square foot range. These systems should be seriously considered when upgrading or constructing new facilities.

Resources

Anderson, Nathaniel. 2012. [Interview]. Research forester. Missoula, MT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Forest Products Laboratory. 2004. Wood biomass for energy. Madison, WI: U.S. Department of Agriculture, Forest Products Laboratory. 3 p.

IEA Bioenergy International Executive Committee. Sustainable production of woody biomass for energy. 2002. 12 p.

Kerns, Brian. 2012. [Interview]. Engineer. Missoula, MT: University of Montana.

Sadaka, S. [Date unknown.] Gasification, producer gas, and syngas. Little Rock, AR: University of Arkansas. 8 p.

Web sites

Ashden
<http://www.ashden.org>

Community Power Corporation
<http://www.gocpc.com>

UM-Bioenergy.org
<http://www.um-bioenergy.org>

Vert Energy Ltd
<http://www.vert-energy.co.uk/what-is-biomass.html>

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Charles Showers, licensed professional engineer, became engineering program leader at MTDC in 2002 after serving 3 years as operations program leader. Showers came to MTDC after 9 years as assistant forest engineer on the Payette National Forest. He began his Forest Service career on the Boise National Forest after 8 years as a construction project engineer with the Idaho Transportation Department.

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Library Card

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Biomass gasification is partial combustion of a carbon-rich material; gasification and pyrolysis can convert biomass into a variety of liquid and gas biofuels—green energy sources. Large combined heating and power (CHP) systems are an economical way to supply heat, power, or combined heat and power. The Missoula Technology and Development Center looked at factors that limit the practical use of small CHP systems.

Keywords: alternative energy, downdraft gasifiers, forest health, fossil fuels, greenhouse gases, producer gas, pyrolysis, renewable energy, safety at work, updraft gasifiers

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